Spin-two models for HH

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HH subgroup meeting

A spin-two resonance? Origin

Gravity in more than 4D

graviton lives everywhere
dimensions compactified
KK-gravitons
spin-two massive particle
with couplings inherited
from gravity

scale of compactification
—> mass of the resonance
—> scale of interactions

interactions
to stress-tensor

New strongly-coupled sector

new strong sector
new mesons and baryons
spin-two mesons
propagation and interactions
described by Fierz-Pauli

scale of confinement
—> mass of the resonance
—> scale of interactions

interactions
Lorentz invariance and CP

A spin-two resonance? Interpretation

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GAUGE-GRAVITY
DUALITIES
HOLOGRAPHY

Indistinguishible in 1->2 decays FOK, GUIMARAES, LEWIS, VS. 1203.2917

From Gia Dvali: "Quantum Gravity with BHs at TeV: exactly same pheno"

A spin-two resonance? Higgs, DM, …

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These models have other interesting features:

Composite Higgs models

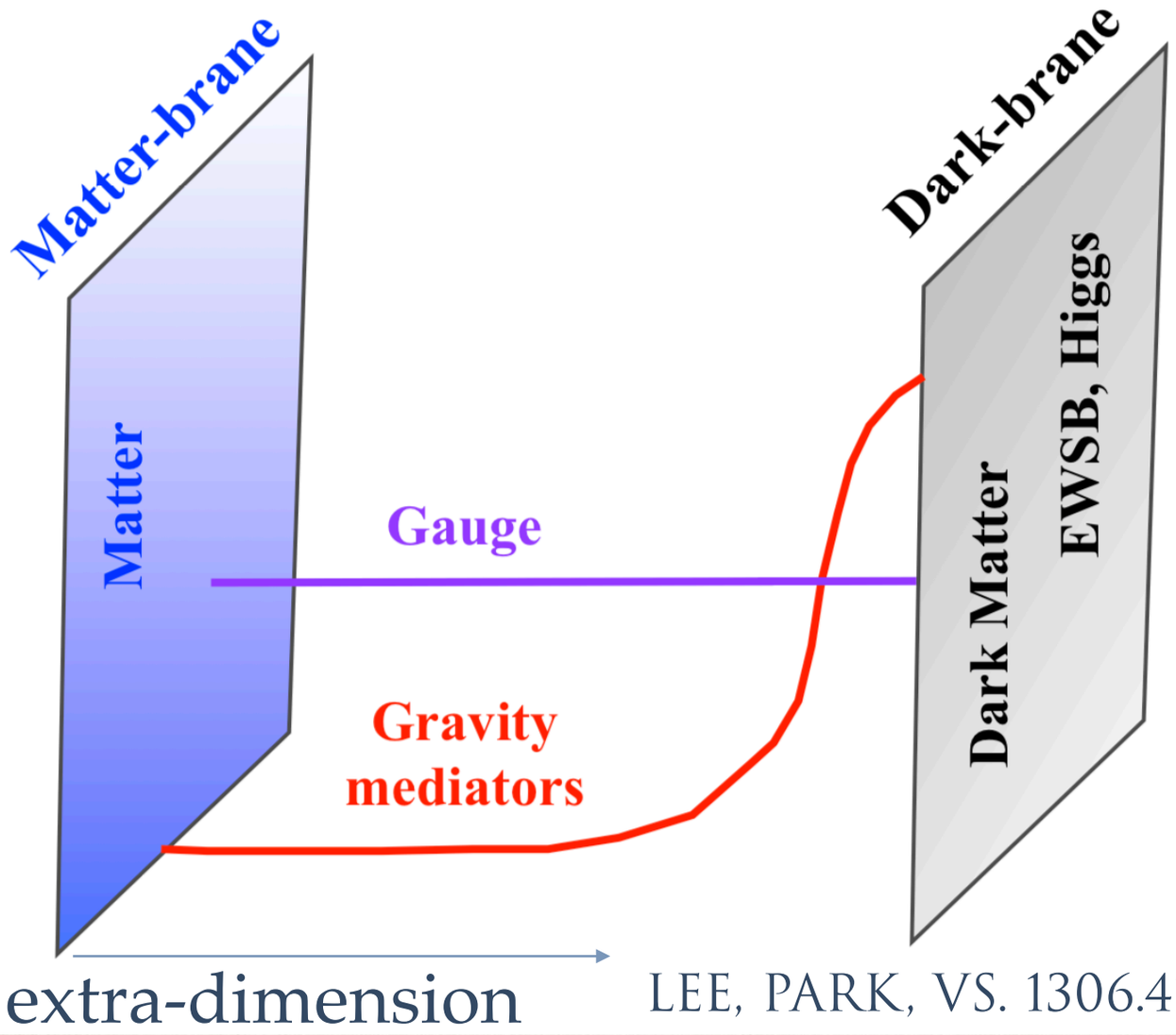
Dark Matter candidates

Flavour

Neutrino masses

related to the couplings/mass of the spin-two

A spin-two resonance in Extra-Dimensions



LEE, PARK, VS. 1306.4107

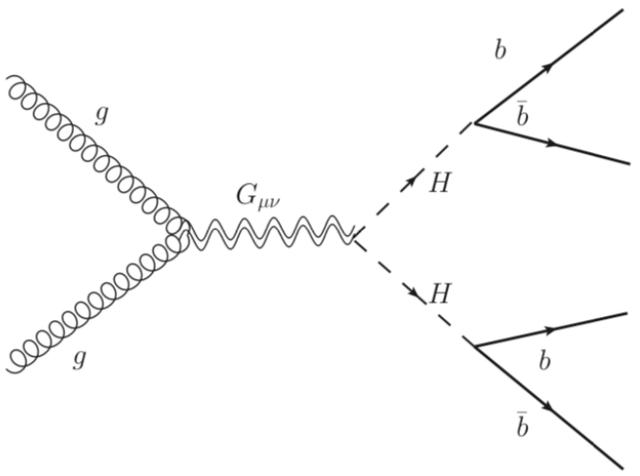
Most intuitive picture

$$\mathcal{L} = -\frac{c_i}{\Lambda_G} G_{\mu\nu} T_i^{\mu\nu}$$

Graviton **G** couples to SM via the stress tensor **T**
Interaction depends on the species **i**, and it is suppressed by scale **LambdaG**

ci depends on the *overlap* of KK-graviton to SM fields
graviton lives near TeV brane (right) where EWSB happens
fields on the right will have larger couplings
==> Higgs=(**h**, **W**, **Z**) and maybe **tops/bottoms**

Production via gluon fusion

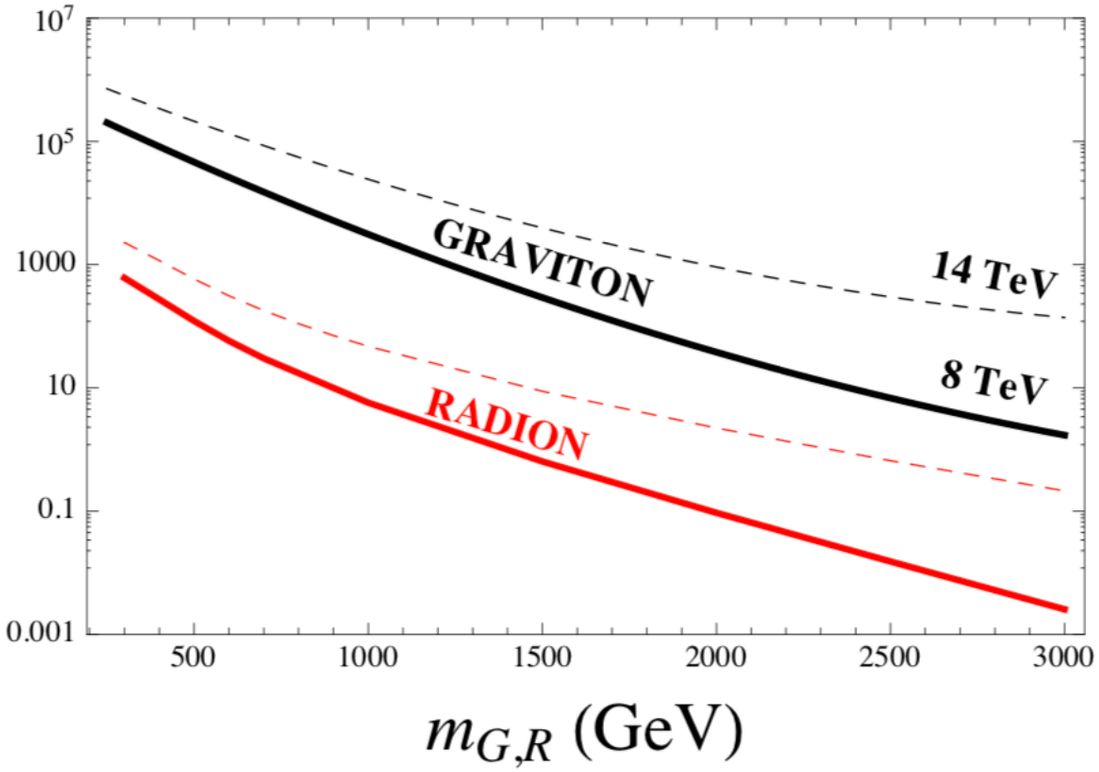


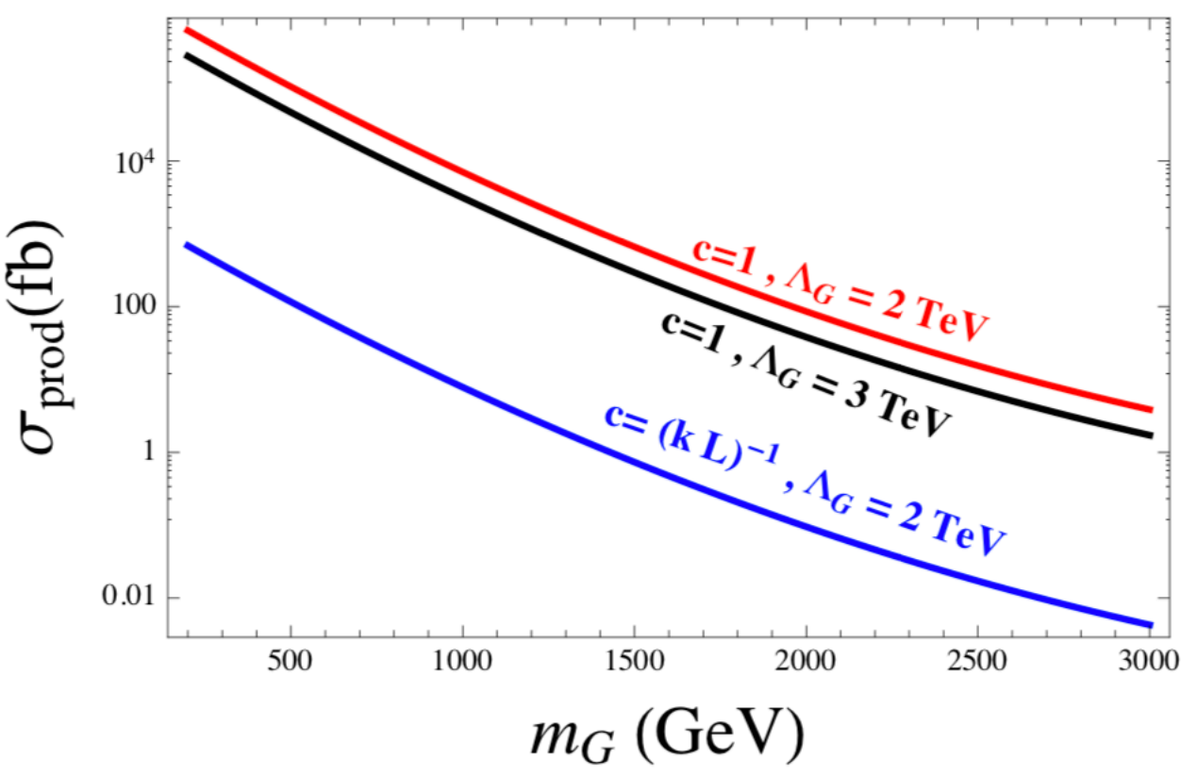
Graviton cross section bigger than radion

more degrees of freedom and
interesting Lorentz structure

GOUZEVITCH, OLIVEIRA, ROJO,
ROSENFELD, SALAM, VS. 1303.6636

$$\frac{\sigma_{\text{prod}}\,(\text{fb})}{c^2} \qquad \frac{\Lambda^2}{(3\,\text{TeV})^2}$$





Main decay modes

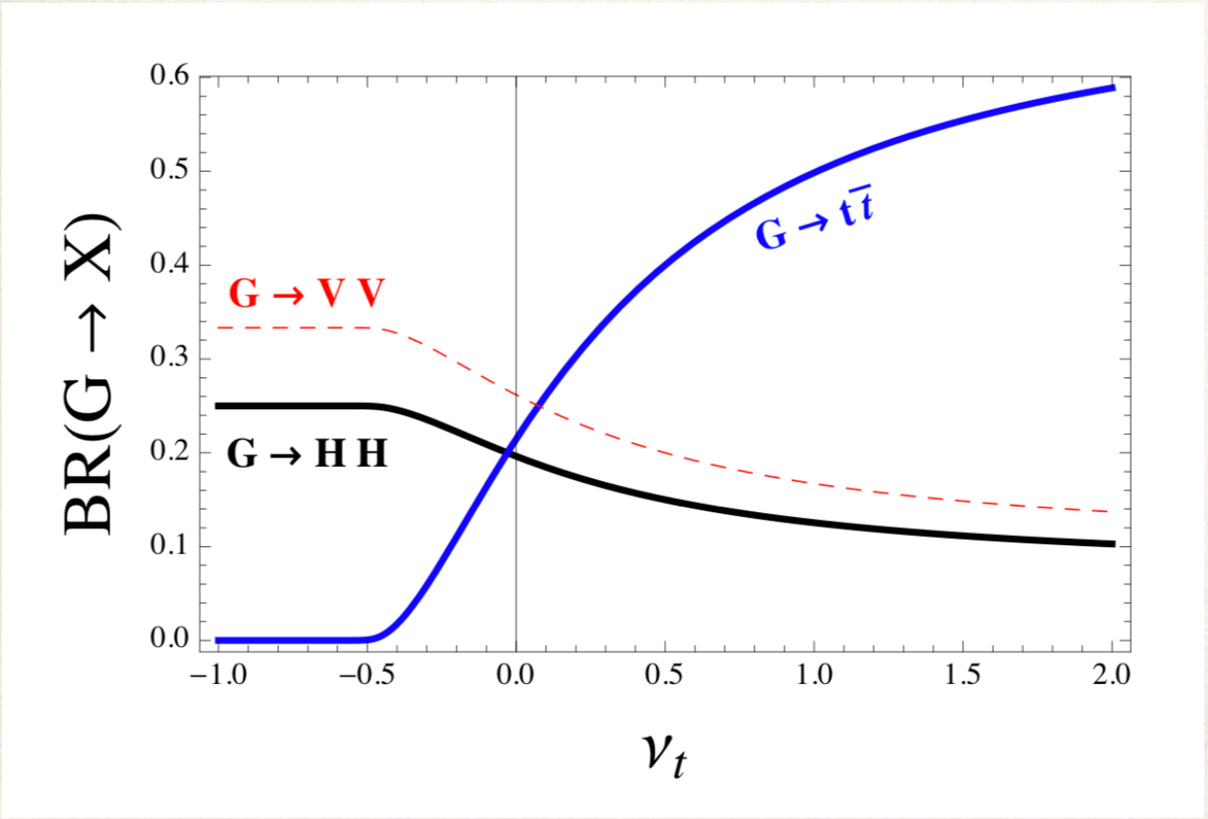
GOUZEVITCH, OLIVEIRA, ROJO, ROSENFELD, SALAM, VS. 1303.6636

1. To Higgses, W's and Z's

$$\Gamma(G \to HH) = \Gamma(G \to Z_L Z_L) = \Gamma(G \to W_L^+ W_L^-)/2 = \frac{1}{960\,\pi}\,\frac{m_G^3}{\Lambda_G^2}$$

2. To photons and gluons

$$\Gamma(G \to gg) = 8\Gamma(G \to \gamma\gamma) \simeq 8\frac{\Gamma(G \to HH)}{kL} \simeq 10^{-1}\Gamma(G \to HH)\ .$$



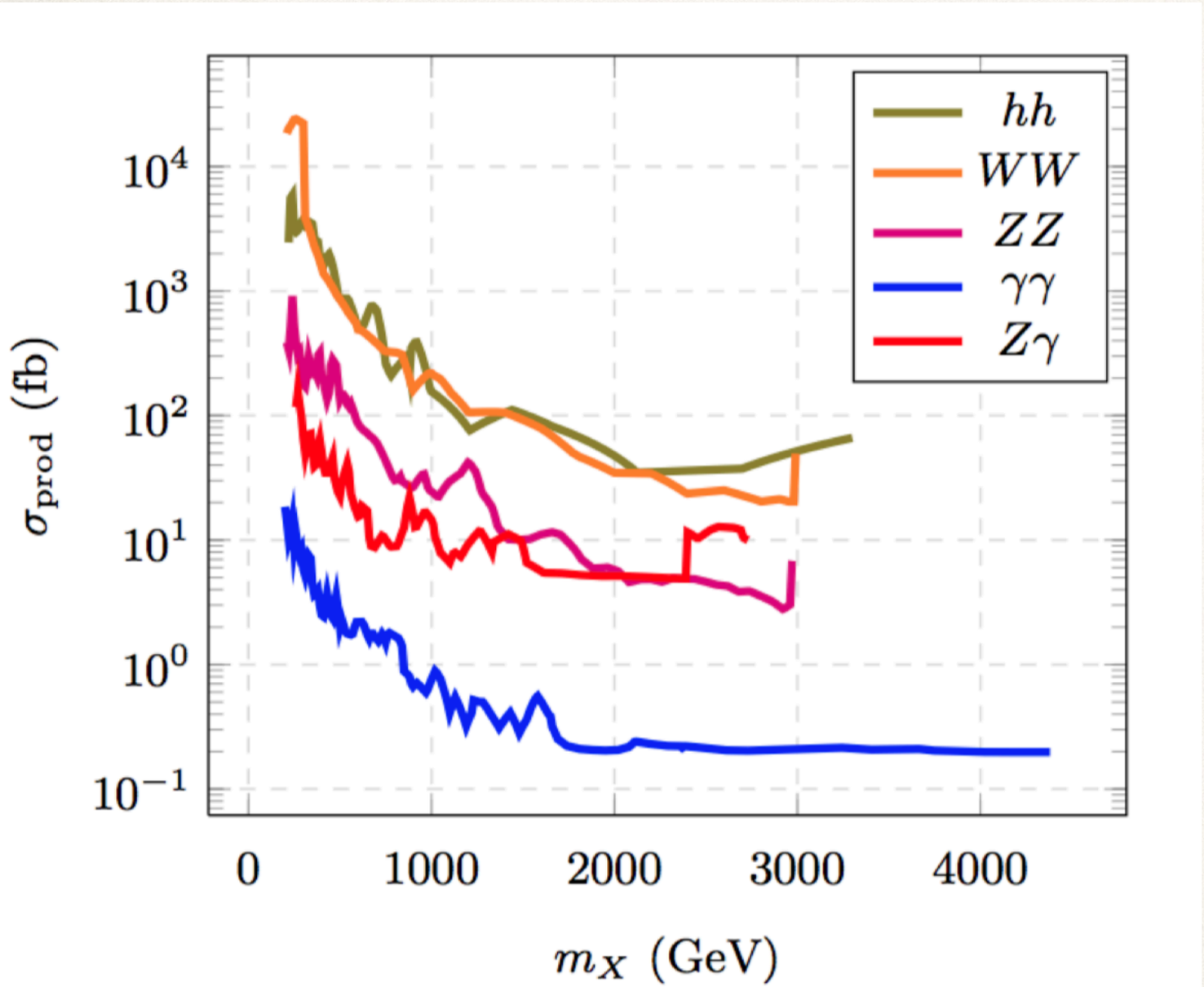
3. To third-generation fermions

$$\Gamma(G \to t\bar{t}) = \frac{1}{240\,\pi}\,f(\nu_t)^2\,\frac{m_G^3}{\Lambda_G^2}$$

depends on fermion localization in the extra-dimension

Spin-two after Run2

All these channels can be searched for at the LHC
HH and WW give particularly large limits



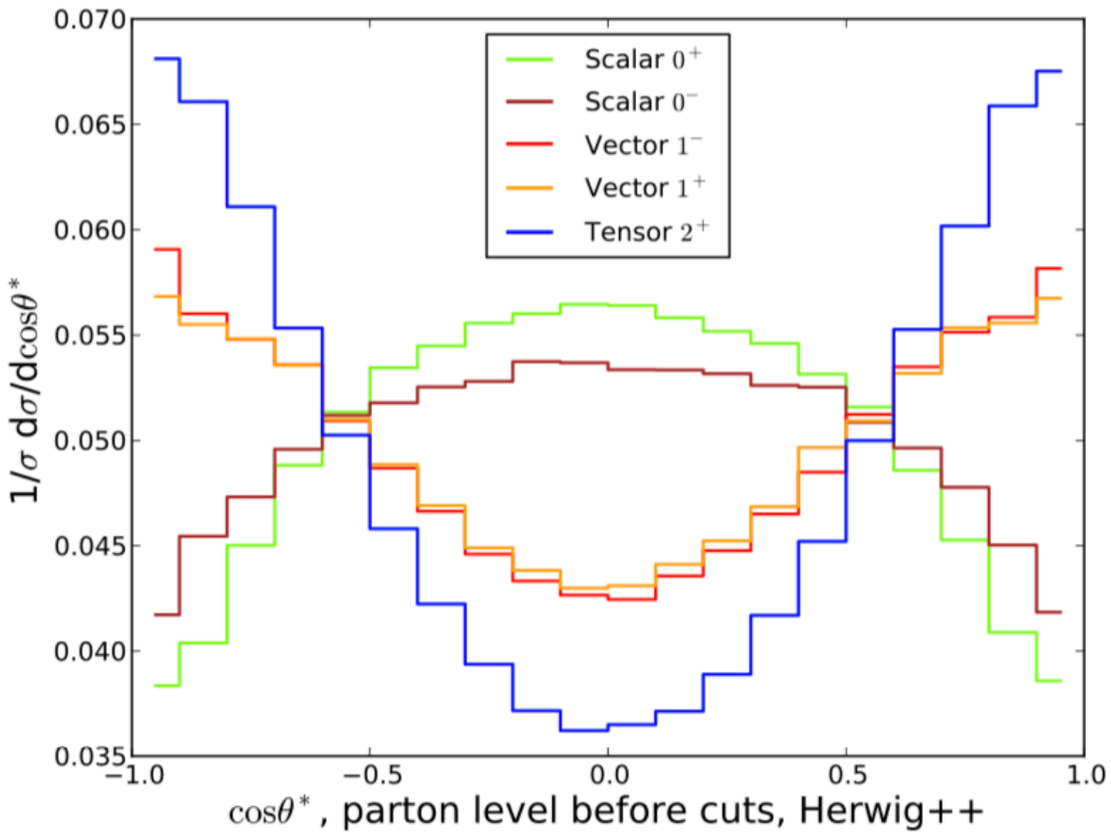
example in
DILLON, VS. 1603.0955
connection to Composite Higgs

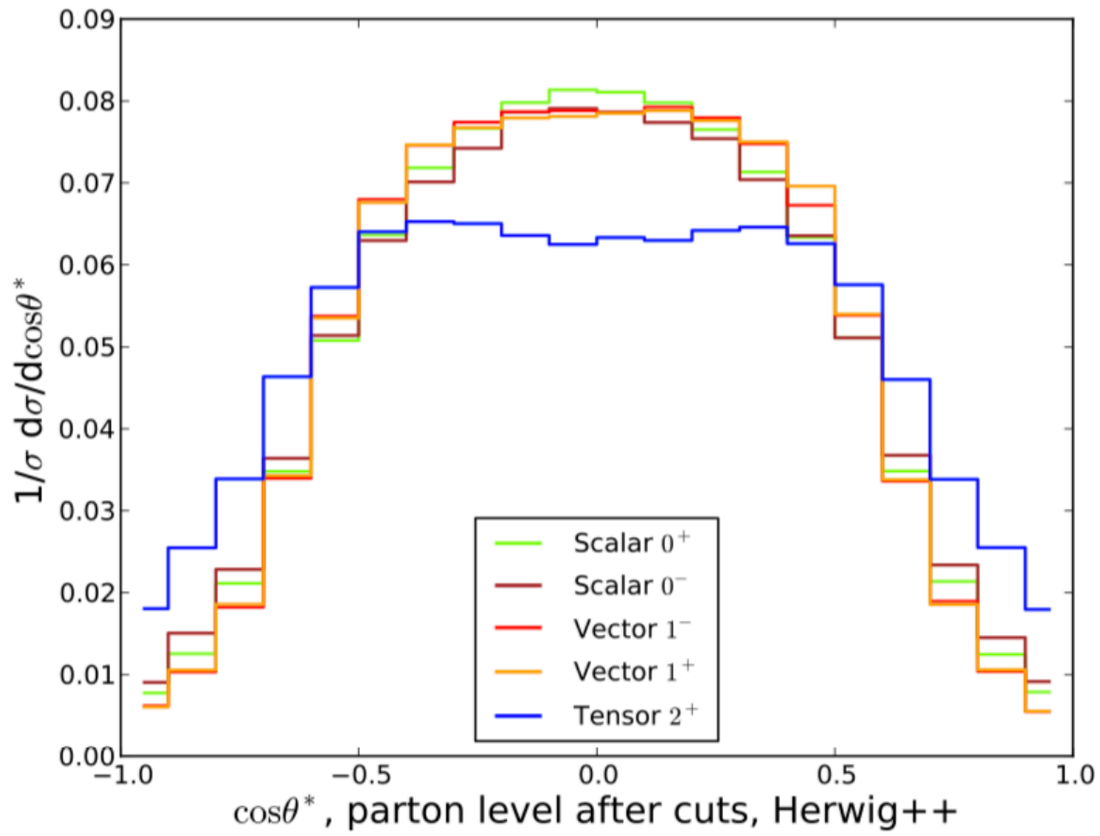
Run2 re-interpretation
assuming BR=1 to each state

Characterising a spin-two HH

Spin-two resonances have different couplings to HH than a simple scalar or a radion

Were a HH resonance be discovered, spin/CP could be obtained as in ZZ resonances





E.G. ENGLERT, HACKSTEIN, SPANNOWSKY. 1010.0676

Summary

- TeV*ish* spin-two resonances appear in many extensions of the SM. They exist in the SM at lower scales in the form of QCD mesons f2, pi2, …

- Their origin can be new physics in the form of **new dimensions of space** or a **new strongly-coupled** sector: **KK-graviton** or **glueball** meson. These two are related by holography

- In both cases, the interactions with SM are determined by **symmetries**

- In models where there is a **connection** between that new physics and **EWSB**, there is a preferential decay to Higgs degrees of freedom (HH, WW, ZZ)

- If the model also tries to explain **fermion mass hierarchies**, the spin-two may also have sizeable decays to third-generation quarks

- In these models, there are new **opportunities** to explain the lightness of the Higgs (composite Higgs), Dark Matter and other issues with the SM